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Twelve worlds: A geo-demographic comparison of global inequalities in mortality

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ABSTRACT

Objective: The aim of this study was to identify clusters of nations grouped by health outcomes in order to provide sensible groupings for international comparisons. The utility of this approach is demonstrated by comparing life expectancy and a range of health system indicators within and between each cluster.

Methods: Age- and sex-specific mortality data for 190 member states were extracted from the Burden of Disease Estimates statistics produced by the World Health Organization. A hierarchical cluster method was used to identify groupings of countries that are homogeneous in terms of mortality rates.

Results: 12 clusters of countries were identified. The average life expectancy of each cluster ranged from 81.5 years (cluster 1) to 37.7 years (cluster 12). The two highest ranked clusters were dominated by Western European countries, Australia, Japan and Canada. Cluster 3 included the UK and USA. The four clusters with the lowest life expectancies were characterised by different configurations of African countries. Health system indicators for workforce, hospital beds, access to medicines and measles vaccination corresponded well with a clear association with cluster life expectancy. On a per capita basis, worldwide health spending was concentrated within the three highest life expectancy clusters, especially cluster 3 containing the USA.

Conclusions: Considerable inequalities in life expectancy and healthcare are made clearer when viewed across clusters of countries grouped by health outcomes. This geo-demographic taxonomy of global mortality has advantages over traditional more ad hoc systems for comparing global health inequalities and for deciding which countries appear to have the most comparable health outcomes.

Introduction

There is growing interest in inequalities in health within and between countries. Cross-national comparisons have tended to note rapidly rising socioeconomic and geographical inequalities in health, particularly over the last 20–30 years.[1–3] Further, international organisations such as the World Health Organization (WHO), the World Bank, United Nations Children's (Emergency) Fund (UNICEF) and the United Nations Development Programme have recognised that widespread and growing inequalities in health are a key area of policy concern. However, in comparing health inequalities between countries, nations are often placed in traditional groupings: by continent, region, membership of organisations such as the European Union or Organization for Economic Cooperation and Development (OECD), and analytical groupings such as WHO regions. For example, New Zealand is routinely compared with countries such as the UK or Australia on the basis of proximity, population size or colonial history. But are these nations really the most comparable? To answer this question, nations can be grouped independently of any presumed association to identify those that appear to be the most comparable in some self-determining way. In this paper we seek to show the extent to which such a view of world health inequalities governed by colonial, historical or geographic constructs of nations may be misplaced when we instead group nations by their actual health outcomes.

Novel approaches to geo-demographic classification using cluster techniques have recently emerged in the study of health inequalities in the USA, the UK and internationally.[4–6] This last study considered international inequalities in mortality in adults and children, with nation-states stratified into three mortality groups (better-off, mid-level and worse-off) and by risk factors associated with health inequality. There are, however, few studies of this kind and even fewer exploring global inequalities in health with geo-demographic methods using clustering techniques. A study such as this does not place nations into preconceived categories, but instead attempts to show how the world appears when classified by health outcomes, if the outcomes themselves are used to group nations. Further, it could be argued that more detailed descriptions of health outcomes should produce a more meaningful summary of health inequalities. So here we utilise two dozen separate mortality rates stratified by age and sex to group countries, *rather* than using simple summary measures such as life expectancy to group them by rank.

With the availability of new and better quality WHO life expectancy data for member states for the year 2001 it was possible to undertake a cluster analysis of global mortality to identify what transpired to be 12 geo-demographic clusters, known here as '12 worlds', each consisting of countries that are broadly homogeneous in mortality profile, accounting for population age and sex structures. These worlds are a novel structured representation of global health inequalities using all-cause mortality and in part reflect core, semiperiphery and periphery typology or the more popularly known First, Second, Third and Fourth World geo-political classification system.[7] Finally, after next explaining how the clusters were derived and describing each, the life expectancies and health system indicators of the countries allocated to each world cluster are explored further to show the extent to which there is wider validity in this clustering.

Data and Methods

Data

Age- and sex-specific population and mortality data (males and females, <1 year, 1–4 years, and 5-year age groups from 5 to 100+ years) for 190 member states were extracted from life tables associated with the Burden of Disease Estimates statistics produced by the WHO. In many of the world's poorest countries there is no effective vital registration system. For approximately one-third of WHO member states little is known about the actual levels of adult mortality, particularly in ages below 60. For countries where data were missing or deemed unreliable by the original researchers, estimation techniques were used.[8–10] In addition, indicators of country health system performance including access to affordable and essential medicines, numbers of working physicians and hospital beds, public and private healthcare spending, and infant measles vaccination were sourced from the Universities of Sheffield and Michigan Worldmapper collaboration datasets.[11]

Cluster analysis

Cluster analysis was used to classify all 190 countries into groups that are homogeneous in terms of health outcomes. To account for differences in the age and sex structure of mortality between countries, rather than simply the absolute differences in mortality, a dissimilarity matrix of 190 by 190 countries was calculated using the sum of the absolute differences in the numbers of deaths for males and females in each 5-year age group standardised to the world 2001 population. That is, if each country had the world population, but it experienced local age-/sex-specific mortality rates, how many more or fewer people would die when the discrepancies for each group were summed between each possible pair of countries. The resulting dissimilarity matrix enabled us to show for each country the difference in the number of world deaths if one country's death rates were used compared with another country's death rates. The pair of countries which has the most similar age/sex mortality profiles were Saudi Arabia and the Libyan Arab Jamahiriya. The two countries separated by the highest absolute numbers of deaths having standardised for their age/sex structure were Japan and Zimbabwe.

To help visualise what is being calculated an analogy from the cartography of the imagination may be useful. Redrawing worlds helps to make reality visible.[12, 13] An earlier pioneer of the application of quantitative techniques in geographical and cartographic work once described how the globe might look if distorted so that distances were in proportion to the deaths of soldiers in all wars.[14, 15] He hypothesised that Moscow and Berlin would be at opposing poles on such a redrawn globe. The dissimilarity matrix calculated here is the distance matrix that would have to be observed were the globe to be redrawn so that distances between countries were proportional to the different chances of people of each age and sex dying in each place. Those countries within each cluster would have to be positioned on this redrawn globe closest to one another. Those clusters furthest apart should be drawn at apposing poles. The cluster analysis described here is akin to describing what new continents would look like, were future tectonic movements to be governed by the strength of inequalities in the premature deaths of humans rather than the forces of gravity and resistance of friction.

Given the small number of cases (190 countries) in the analysis, a hierarchical cluster method was adopted. Countries were classified using an agglomerative technique beginning with single country clusters and merging these with other clusters until increasingly dissimilar clusters were merged, resulting in large decreases in the level of similarity in clusters. Therefore, larger clusters created at later stages contained smaller more similar clusters created at earlier stages of the agglomeration process. To measure similarity, a Euclidean distance measure and a "within-groups linkage" clustering algorithm was used where the average distance between all possible inter- or intra-cluster pairs in the resulting cluster was minimised so that the within-cluster variance was diminished. Euclidean distances were used, and the absolute differences summed without adjusting for age, so that each death and each discrepancy was given equal value for men and women, whether the deaths occurred at ages 0, 50 or 100. Wherever the least absolute differences in deaths were observed between countries then countries were grouped into clusters, and as the agglomeration process continued countries and clusters were merged into further clusters. This method was also utilised for practical and theoretical expediency as it optimised mortality homogeneity within clusters and identified the fewer typical clusters containing larger numbers of countries rather than the many exceptional clusters containing just a few countries.

The iterative process began by combining the two countries with the lowest Euclidean distance (highest similarity) into a cluster and then the next country with the lowest Euclidean distance to either of these first two countries. If this third country was closer to a fourth country than it was to the clusters formed by the combination of the mortality profiles of the first two, then the third and fourth countries become a second two-country cluster; otherwise, the third country was incorporated into the first cluster. The process of adding countries to existing clusters or creating new clusters was repeated until all countries had been allocated to a cluster. At this point the process ended and the clustering dendrogram emerged (fig 1). The dendrogram had to be divided manually at key breaks in the tree structure to derive the 12 world clusters. Clusters were based on the contiguous country groupings in the left-most branches of the tree where there were small differences between countries. Link lines further to the right of the dendrogram indicated increasing dissimilarity between country agglomerations. Thus the entire process is independent of subjective intervention until the final stage, but we show here the full results so that the reader can see how the world came to be divided into 12.

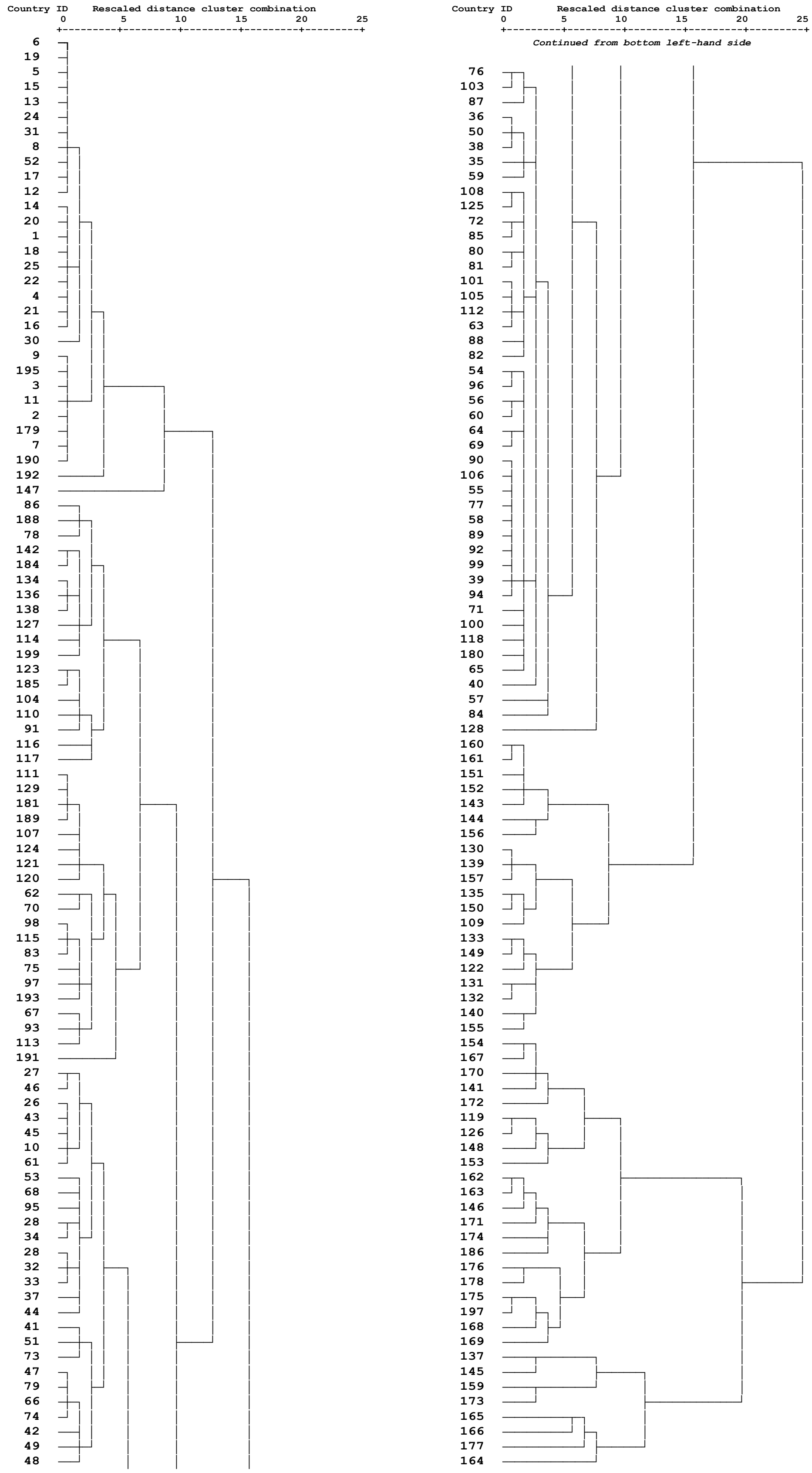

Figure 1. Clustering dendrogram

Validation of cluster homogeneity

Life expectancies from birth were calculated for each of the 190 countries using the "Chiang II method" because this approach is not susceptible to errors resulting from a count of zero deaths in a particular age–sex group (for one small country for one age–sex group there were no deaths recorded in 2001).[16] Life expectancy was calculated for males and females separately, and, from these figures, the total population life expectancy for each country was estimated from the male/female population-weighted average. For each cluster, the population-weighted average life expectancy of all constituent countries was calculated. Six health system indicators were also derived to compare key aspects of the health systems in each of the clusters. For each identified cluster, summary measures of hospital beds, working physicians, public and private healthcare expenditures, affordable drugs and measles vaccinations were calculated using a population-weighted aggregation, and rates were estimated using the corresponding total cluster populations as denominators.

Results

Twelve groups of countries were identified using the hierarchical cluster analysis dendrogram (table 1; fig 1). The clusters were ranked by their average life expectancy from 1 (highest) to 12 (lowest) and a residual 13th outlier group consisting of Botswana and Zimbabwe was manually created. These two countries were highly dissimilar within the clusters that they were originally allocated to (with long horizontal lines linking them to a cluster in the dendrogram) and so were given a separate grouping. Patterns of mortality for Zimbabwe and Botswana, as in other Southern African countries, reflect a high prevalence of HIV/AIDS deaths but also limitations in the ascertainment of mortality rates.[17]

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Life expectancy years					
Cluster	**Countries (n)**	**Male**	**Female**	**Total**	**Difference from cluster 1 total**
1	8	77.9	85.0	81.5	0.0
2	10	76.0	82.6	79.3	2.2
3	12	74.7	80.0	77.4	4.1
4	27	70.7	77.5	74.1	7.4
5	18	68.7	72.7	70.7	10.8
6	26	66.5	72.1	69.3	12.2
7	20	64.2	69.2	66.7	14.8
8	18	60.3	62.0	61.2	20.3
9	20	53.5	56.4	54.9	26.6
10	9	47.6	50.0	48.8	32.7
11	12	43.6	46.0	44.8	36.7
12	8	36.5	38.9	37.7	43.8
*	2	37.4	36.8	37.1	44.4
* Outlier group of 2 countries Botswana and Zimbabwe					

Table 1. Cluster male, female, and comparative life expectancy

Unsurprisingly, affluent and industrialised nations dominate the three highest life expectancy ranked clusters and average life expectancy ranged from 81.5 to 77.4 years (fig 2; see online table). Japan, Australia, Switzerland, Sweden, Iceland and three small European city states (Andorra, Monaco and San Marino) are included in the highest ranked cluster. New Zealand is included along with Singapore, Canada, France, Spain, Italy and Israel in cluster 2. The third ranked cluster included the USA, Cuba, and the western European countries of Belgium, The Netherlands, Luxembourg, Germany, Denmark and the UK.

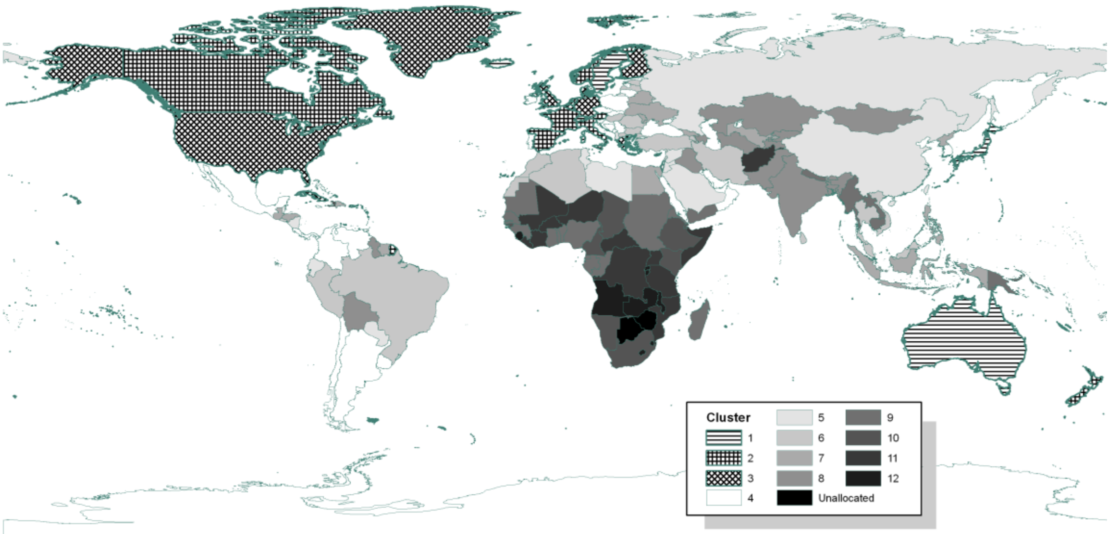


Figure 2. World map of country cluster life expectancy

World	Country		Male	Female	Total	Cluster
1	9	Japan	78.0	85.5	81.9	81.5
1	195	San Marino	77.7	84.9	81.4	81.5
1	190	Monaco	77.0	85.0	81.1	81.5
1	3	Australia	77.5	82.9	80.2	81.5
1	11	Switzerland	77.4	83.0	80.2	81.5
1	2	Sweden	77.7	82.5	80.1	81.5
1	179	Andorra	76.4	83.6	80.1	81.5
1	7	Iceland	78.2	81.3	79.7	81.5
2	16	France	75.7	83.2	79.5	79.3
2	4	Canada	76.7	82.2	79.5	79.3
2	21	Italy	76.3	82.4	79.4	79.3
2	20	Spain	75.3	82.9	79.2	79.3
2	14	Austria	76.1	82.1	79.2	79.3
2	1	Norway	76.1	81.6	78.9	79.3
2	25	Singapore	76.5	81.2	78.8	79.3
2	18	New Zealand	76.2	81.3	78.8	79.3
2	22	Israel	76.3	81.0	78.7	79.3
2	30	Cyprus	74.6	79.0	76.8	79.3
3	15	Luxembourg	75.0	82.1	78.6	77.4
3	5	Netherlands	75.8	80.8	78.3	77.4
3	19	Germany	75.1	81.2	78.2	77.4
3	6	Belgium	74.8	81.3	78.1	77.4
3	31	Malta	75.9	80.3	78.1	77.4
3	24	Greece	75.4	80.6	78.1	77.4
3	13	Finland	74.5	81.4	78.0	77.4
3	12	United Kingdom	75.1	79.9	77.6	77.4
3	52	Cuba	74.9	79.9	77.4	77.4
3	17	Denmark	74.8	79.7	77.3	77.4
3	192	Niue	70.0	85.0	77.2	77.4
3	8	United States	74.4	79.5	77.0	77.4
4	26	Portugal	72.8	80.3	76.7	74.1
4	10	Ireland	73.8	79.3	76.5	74.1
4	43	Chile	73.1	79.5	76.3	74.1
4	45	Costa Rica	73.8	78.9	76.3	74.1
4	27	Slovenia	72.1	79.3	75.8	74.1
4	32	Czech Republic	71.9	78.9	75.5	74.1
4	44	Kuwait	75.1	75.8	75.4	74.1
4	46	Uruguay	71.0	79.5	75.4	74.1
4	61	Panama	72.2	78.4	75.2	74.1
4	28	Republic of Korea	71.2	78.8	75.0	74.1
4	29	Barbados	70.5	78.6	74.7	74.1
4	33	Brunei Darussalam	73.2	76.0	74.5	74.1
4	53	Mexico	71.8	76.9	74.4	74.1
4	37	Poland	69.9	78.2	74.2	74.1
4	34	Argentina	70.1	78.0	74.1	74.1
4	68	Venezuela	70.9	76.8	73.8	74.1
4	95	Dominica	71.8	75.8	73.8	74.1
4	42	Slovakia	69.3	77.4	73.5	74.1
4	48	Croatia	68.9	77.2	73.1	74.1
4	41	Lithuania	67.7	78.0	73.1	74.1
4	66	Bosnia Herzegovina	69.3	76.4	72.9	74.1
4	79	Jamaica	71.0	74.4	72.7	74.1
4	49	United Arab Emirates	70.8	74.7	72.2	74.1
4	47	Qatar	70.8	74.5	72.1	74.1

Table 2 Life expectancies from birth (years) by country and cluster rank

4	51	Bahamas	68.8	75.2	72.0	74.1
4	74	Oman	69.5	74.7	71.9	74.1
4	73	Colombia	66.7	74.7	70.7	74.1
5	40	Bahrain	72.2	73.4	72.7	70.7
5	180	Cook Islands	69.6	73.9	71.7	70.7
5	92	Tunisia	69.0	73.5	71.2	70.7
5	71	Saint Lucia	69.5	72.9	71.2	70.7
5	94	China	69.8	72.7	71.2	70.7
5	55	Antigua & Barbuda	68.5	73.6	71.1	70.7
5	106	Syrian Arab Republic	68.7	73.2	71.0	70.7
5	90	Jordan	68.6	73.5	70.9	70.7
5	77	Saudi Arabia	68.4	73.6	70.8	70.7
5	39	Saint Kitts & Nevis	68.8	72.5	70.7	70.7
5	58	Libyan Arab Jamahiriya	68.3	73.2	70.6	70.7
5	89	Paraguay	68.3	72.9	70.6	70.7
5	100	Ecuador	67.6	73.2	70.4	70.7
5	99	Belize	67.7	72.6	70.1	70.7
5	65	Albania	66.3	73.3	69.7	70.7
5	118	Nicaragua	67.1	72.1	69.6	70.7
5	57	Russian Federation	58.9	72.3	66.0	70.7
5	84	Maldives	63.8	64.4	64.1	70.7
6	38	Hungary	67.3	76.3	72.0	69.3
6	59	Malaysia	69.3	74.6	71.9	69.3
6	60	TFYR Macedonia	68.9	74.9	71.9	69.3
6	56	Bulgaria	68.4	74.8	71.7	69.3
6	35	Seychelles	66.6	76.7	71.7	69.3
6	36	Estonia	65.7	76.5	71.5	69.3
6	64	Mauritius	67.5	75.0	71.3	69.3
6	69	Romania	67.8	74.5	71.2	69.3
6	50	Latvia	65.3	75.9	71.0	69.3
6	96	Sri Lanka	66.6	74.1	70.3	69.3
6	87	Saint Vincent & Grenada.	67.7	72.6	70.2	69.3
6	54	Trinidad & Tobago	67.3	72.6	70.0	69.3
6	80	Lebanon	67.6	72.1	69.9	69.3
6	82	Armenia	66.3	73.1	69.8	69.3
6	81	Fiji	67.8	71.9	69.8	69.3
6	103	El Salvador	66.4	72.7	69.6	69.3
6	125	Morocco	67.6	71.4	69.5	69.3
6	108	Algeria	67.7	71.1	69.4	69.3
6	63	Tonga	68.1	70.8	69.4	69.3
6	112	Viet Nam	66.9	71.8	69.4	69.3
6	76	Thailand	65.8	72.4	69.1	69.3
6	105	Cape Verde	65.7	72.0	69.0	69.3
6	88	Turkey	67.0	71.1	69.0	69.3
6	72	Brazil	65.5	72.0	68.8	69.3
6	101	Iran (Islamic Republic of)	66.5	71.2	68.8	69.3
6	85	Peru	66.2	70.9	68.6	69.3
7	97	Georgia	65.4	72.4	69.0	66.7
7	62	Belarus	62.9	74.2	69.0	66.7
7	75	Samoa	67.0	69.9	68.3	66.7
7	193	Palau	66.4	70.3	68.3	66.7
7	70	Ukraine	62.2	73.3	68.2	66.7
7	113	Moldova, Republic of	64.2	71.7	68.1	66.7
7	83	Philippines	64.2	71.5	67.8	66.7
7	67	Suriname	64.2	70.6	67.5	66.7
7	115	Honduras	64.4	70.3	67.4	66.7

Table 2 (continued) Life expectancies from birth (years) by country and cluster rank

7	98	Dominican Republic	64.1	70.6	67.3	66.7
7	93	Grenada	65.6	68.6	67.1	66.7
7	120	Egypt	65.3	67.8	66.5	66.7
7	124	Solomon Islands	64.7	68.4	66.5	66.7
7	121	Guatemala	63.6	69.1	66.3	66.7
7	189	Micronesia (F States of)	64.7	67.8	66.2	66.7
7	181	Democratic PR of Korea	64.0	68.3	66.2	66.7
7	111	Indonesia	64.5	67.4	65.9	66.7
7	129	Vanuatu	64.4	67.0	65.7	66.7
7	107	Uzbekistan	62.6	68.5	65.6	66.7
7	191	Nauru	58.5	66.4	62.3	66.7
8	117	Mongolia	61.4	68.6	65.0	61.2
8	110	Kyrgyzstan	60.1	68.2	64.3	61.2
8	104	Guyana	61.3	66.7	64.1	61.2
8	123	Sao Tome and Principe	62.9	65.0	64.0	61.2
8	91	Azerbaijan	60.8	66.5	63.7	61.2
8	185	Kiribati	61.7	65.8	63.7	61.2
8	116	Tajikistan	59.9	67.1	63.5	61.2
8	199	Tuvalu	61.8	64.7	63.2	61.2
8	78	Kazakhstan	58.8	67.2	63.1	61.2
8	114	Bolivia	61.2	64.4	62.8	61.2
8	86	Turkmenistan	58.9	66.5	62.7	61.2
8	188	Marshall Islands	60.8	64.4	62.5	61.2
8	138	Bangladesh	61.9	61.8	61.9	61.2
8	136	Comoros	59.9	63.9	61.8	61.2
8	134	Bhutan	60.6	62.8	61.7	61.2
8	142	Pakistan	61.1	61.6	61.4	61.2
8	127	India	60.1	61.8	60.9	61.2
8	184	Iraq	58.8	63.0	60.9	61.2
9	149	Yemen	58.5	61.4	60.0	54.9
9	133	Papua New Guinea	58.4	61.4	59.9	54.9
9	122	Gabon	58.1	60.6	59.3	54.9
9	155	Gambia	56.3	61.1	58.7	54.9
9	140	Nepal	58.7	58.0	58.3	54.9
9	131	Ghana	55.9	59.0	57.5	54.9
9	132	Myanmar	54.7	60.0	57.4	54.9
9	130	Cambodia	53.4	59.1	56.3	54.9
9	139	Sudan	54.2	58.0	56.1	54.9
9	157	Senegal	54.6	57.3	56.0	54.9
9	150	Madagascar	53.4	56.5	55.0	54.9
9	135	Lao People's D Republic	53.7	55.7	54.7	54.9
9	109	Equatorial Guinea	52.4	55.2	53.8	54.9
9	156	Eritrea	52.3	55.1	53.7	54.9
9	144	Congo	51.9	53.9	52.9	54.9
9	161	Benin	51.1	53.4	52.3	54.9
9	152	Mauritania	51.1	53.3	52.2	54.9
9	160	Guinea	50.3	53.9	52.1	54.9
9	143	Togo	50.4	53.2	51.8	54.9
9	151	Nigeria	50.7	52.7	51.7	54.9
10	153	Haiti	45.7	54.8	50.3	48.8
10	141	Cameroon	49.0	50.6	49.8	48.8
10	154	Djibouti	48.1	50.5	49.4	48.8
10	119	South Africa	47.8	50.3	49.1	48.8
10	148	Kenya	48.3	49.6	48.9	48.8
10	167	Chad	47.2	50.4	48.8	48.8
10	126	Namibia	48.5	49.1	48.8	48.8

Table 2 (continued) Life expectancies from birth (years) by country and cluster rank

10	170	Ethiopia	47.0	49.3	48.2	48.8
10	172	Guinea-Bissau	46.2	48.9	47.6	48.8
11	162	United Republic Tanzania	46.0	47.3	46.6	44.8
11	146	Uganda	45.4	47.8	46.6	44.8
11	186	Liberia	44.8	48.1	46.5	44.8
11	163	Côte d'Ivoire	45.2	47.2	46.2	44.8
11	174	Mali	44.5	46.4	45.4	44.8
11	171	Mozambique	43.9	46.1	45.0	44.8
11	168	Democratic Rep Congo	42.3	45.7	44.0	44.8
11	197	Somalia	41.2	45.6	43.4	44.8
11	175	Burkina Faso	42.4	43.6	43.1	44.8
11	176	Niger	42.2	43.4	42.8	44.8
11	169	Central African Republic	42.2	43.4	42.8	44.8
11	178	Afghanistan	41.5	44.0	42.7	44.8
12	159	Rwanda	39.1	42.9	41.0	37.7
12	173	Burundi	38.6	42.5	40.6	37.7
12	137	Swaziland	40.3	40.2	40.3	37.7
12	145	Lesotho	40.2	39.9	40.1	37.7
12	164	Zambia	36.9	37.1	37.0	37.7
12	165	Malawi	36.0	37.1	36.6	37.7
12	166	Angola	34.5	38.6	36.6	37.7
12	177	Sierra Leone	33.1	36.2	34.7	37.7
*	128	Botswana	39.4	38.7	39.0	37.1
*	147	Zimbabwe	37.2	36.5	36.9	37.1

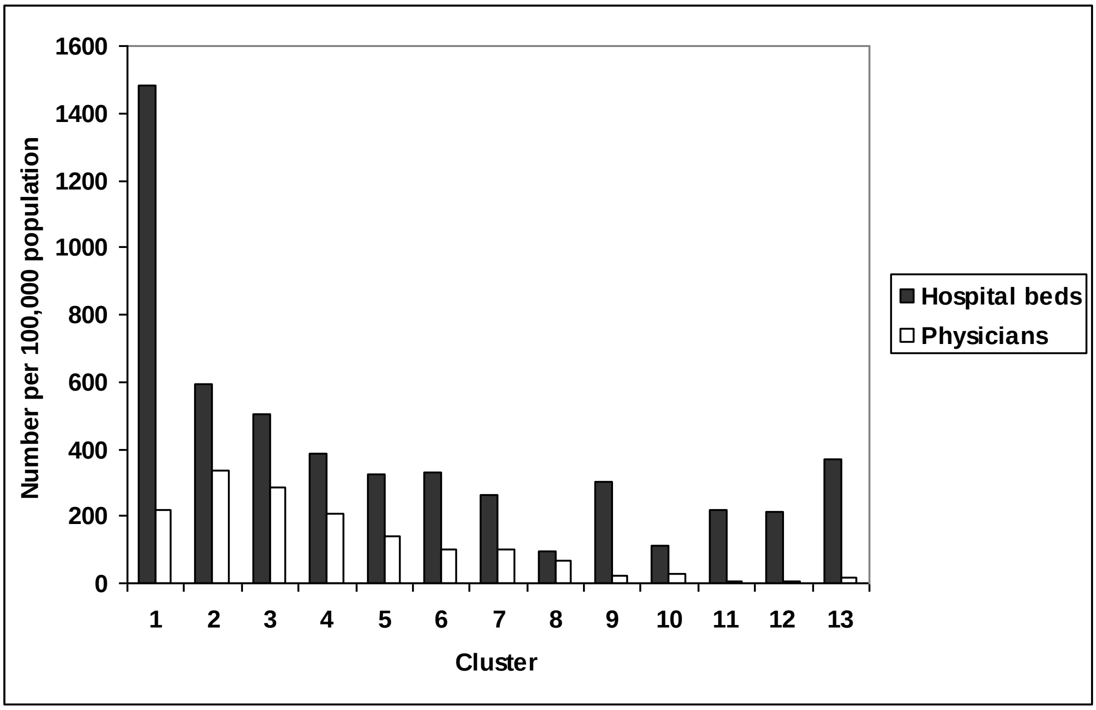
Table 2. (continued) Life expectancies from birth (years) by country and cluster rank

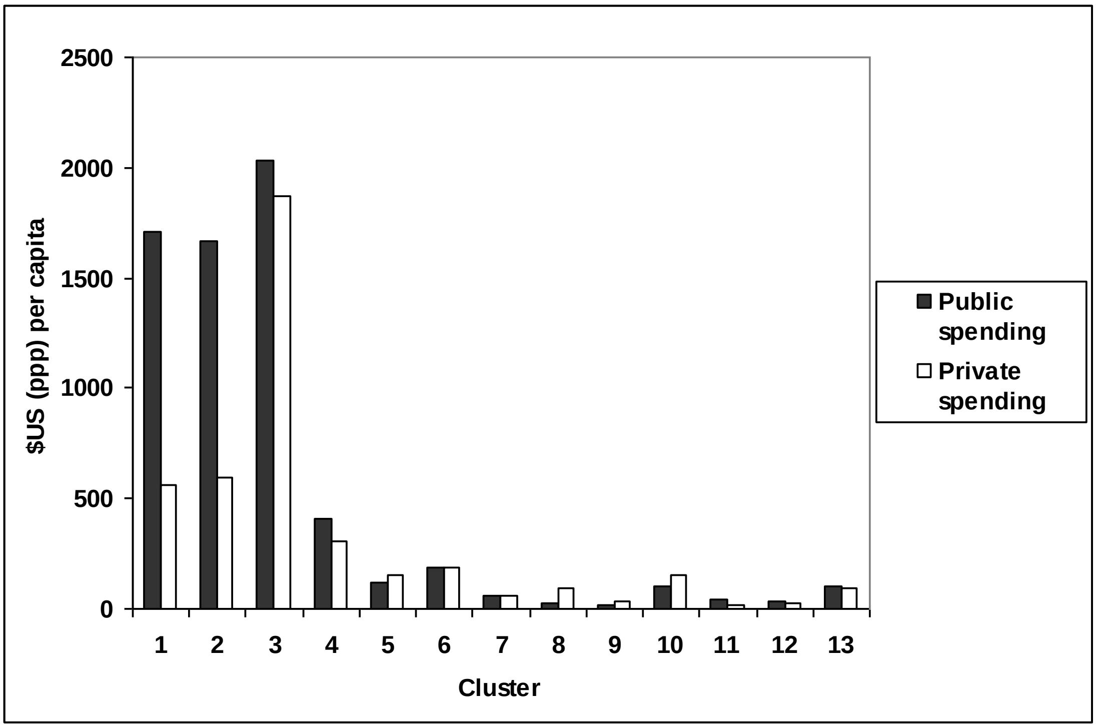
The fourth ranked cluster consists of many Eastern European countries, including Poland, the Czech Republic, Slovakia and Slovenia; wealthy Persian Gulf countries including the United Arab Emirates, Qatar, Kuwait and Oman; and Central and South American countries such as Panama, Columbia, Uruguay and Argentina. The fifth ranked cluster is dominated in population terms by China and the Russian Federation whereas the eighth ranked cluster is dominated by India, Pakistan and Bangladesh. The sixth and seventh middle ranked clusters are more diffuse in their membership and comprised a total of 46 countries. By contrast, mostly African nations with the exception of Afghanistan, Cambodia, Haiti, Myanmar, Nepal, Papua New Guinea and Yemen make up the 51 countries in the five lowest ranked clusters (including the 13th residual group), where average life expectancy ranged from 37.1 to 54.9 years.

In all 12 clusters, average life expectancy is consistently higher for females than for males; however, the gap narrows in lower life expectancy ranked clusters. Cluster population life expectancy differences for the highest ranked cluster compared with other clusters increase dramatically from 2.2 years for cluster 2 to 43.8 years when the highest ranked cluster is compared with the lowest ranked 12th cluster (table 1). This is to be expected as countries with similar age- and sex-specific mortality rates and profiles will also have similar overall life expectancies.

The geography of the 12 worlds is shown as a thematic map which illustrates the subregional variations in world life expectancy distribution (fig 2). Countries that make up traditional geographical concentrations of "similar" countries such as Western Europe, South and Central America, or sub-Saharan Africa are more clearly differentiated. This is possible when countries were visualised in clusters determined through actual health outcomes revealing considerable life expectancy variation within these commonly associated conglomerates of nations.

Health system indicators of the numbers of working physicians and hospital beds per 100,000 population tend to be lower among lower life expectancy ranked clusters (fig 3). The number of hospital beds per 100,000 population was 2.5 times higher in cluster 1 than in cluster 2. Public and private health expenditure in US$ per capita (with dollars adjusted to equivalent in purchasing power parity terms) shows a significant disparity between the three highest ranked clusters, particularly the third ranked cluster with the USA, and all other clusters (fig 3). In this cluster, private and public health expenditure is US$1867 and US$2033 per capita compared with between US$302 and US$26 per capita for private and between US$411 and US$35 per capita for public health expenditure for clusters 4–12 respectively. The percentage of the cluster populations with sustainable access to affordable drugs and the proportion of infants from all births vaccinated against measles mostly follows the same trend across the clusters. The 8th to 12th clusters have markedly lower percentages than the 1st to 7th ranked clusters (fig 3).





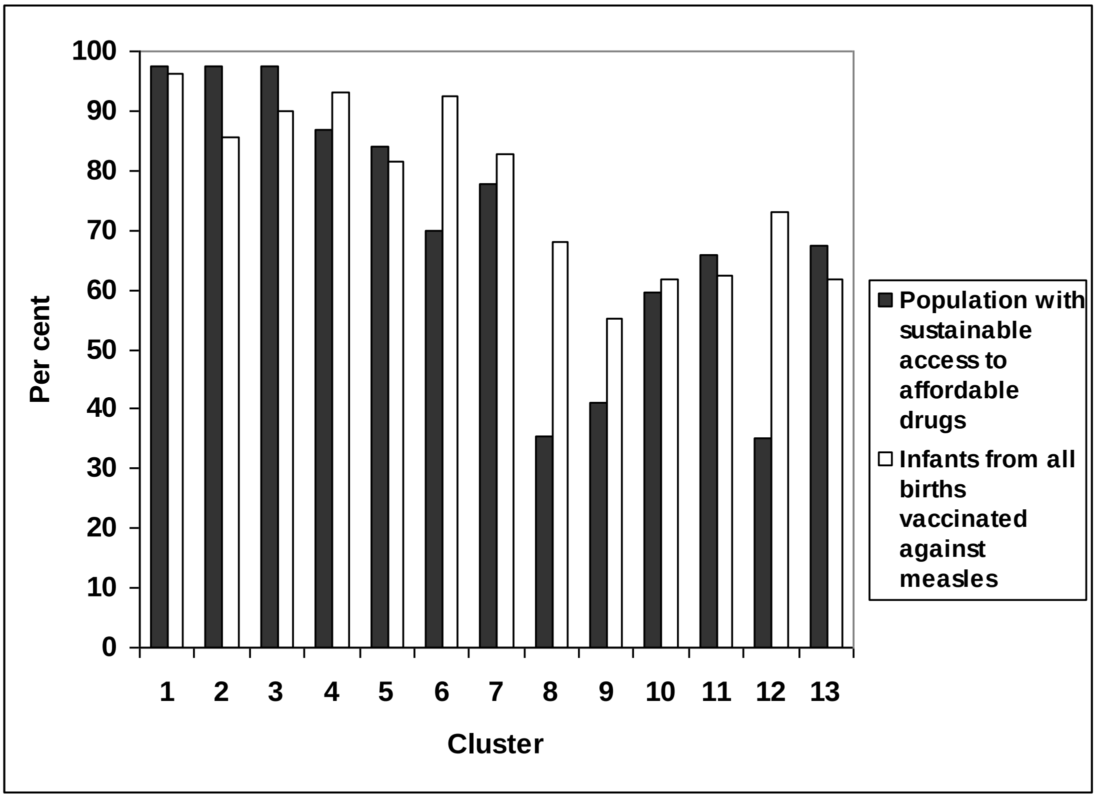


Figure 3. Health system performance indicators by cluster

Discussion

The 12 worlds follow a geo-demographic classification of all-cause mortality for 190 WHO member states and offer a new perspective on comparing international health inequalities using health outcomes rather than preconceived notions of the comparability of countries. Our model questions the rationale for traditional groupings of countries that are considered to have similar health outcomes based on historical, political and colonial determinants. The geography of global health inequalities shown by this classification presents homogeneous subregional groupings of countries. These are differentiated within the lowest life expectancy countries in Africa and in the middle ranked countries of, for example, South Asia, and in the highest life expectancy countries of Western Europe and North America. The comparison of health system indicators across these 12 worlds demonstrates the inequitable distribution of healthcare where those with the greatest need are afforded the least amount of care. The health disparities between these 12 worlds are large, and global institutional policies and interventions to reduce these disparities can benefit through more meaningful summaries of inequality based on health outcomes. The determinants of health inequalities are well recognised, as are the widening health and poverty gaps between and within countries that have coincided with improvements in global health status as measured by gains in life expectancy and the reductions in preventable deaths.[18] Greater knowledge of the problem of global health inequalities can facilitate action such as that of the WHO Commission on Social Determinants of Health to promote debate and the uptake of policies that will reduce inequalities in health within and between countries.[19]

There are few studies that explore global health inequalities using cluster analysis.[6 20] Our study offers a far greater stratification of countries with which to summarise these inequalities than previous studies but also validates the clustering of countries into 12 groups through comparing countries' life expectancies and health system indicators. Given that cluster membership is dynamic, the methodology has potential for the monitoring of global health inequalities over time where once similar countries (eg former Soviet Republics) become more disparate, and vice versa. The main advantage of the hierarchical clustering method used in this study was that no prior assumption on the number of clusters was required and the method was appropriate for the number of countries in the analysis. The arrangement of countries within clusters may not necessarily be what might have been expected if the only measure used for comparison is life expectancy (eg Lithuania, Latvia and Estonia and the UK and Ireland). So to account for variation in the age and sex structure of mortality between countries the sum of the difference between each country in the absolute numbers of deaths by age and sex standardised to the world population was instead used. The dissimilarity matrix makes it possible to compare countries with the most with countries with the least similar age/sex mortality profiles from which country cluster groupings were derived. Our method is also validated with the life expectancy and health system performance indicators that are negatively correlated with cluster all-cause mortality, and shows clear differentiation between country groupings. These indicators demonstrate a high degree of homogeneity within the country groupings.

Our study has limitations. First, although the WHO mortality were the best available, the self-reported registration data have varying completeness, coverage and reliability.[21] For a large number of the world's poorest countries, particularly in Africa, there is no effective vital registration system at birth or death.[22] For these countries where there are no recent or available data, mortality is estimated using standard life tables applied to infant and adult mortality that is often projected from infrequent census and demographic and health surveys estimates.[10] It is possible that these procedures may have influenced the grouping of countries into clusters causing a degree of misclassification bias. Second, it is not possible to make assertions regarding trends in global health disparities and the changing membership of clusters of countries over time. The clustering methodology used a fixed agglomeration process which resulted in several outliers within higher life expectancy-ranked clusters which had to be manually reassigned. The optimal number of clusters was derived from the set of nested clusters visualised on the dendrogram. There were other possible country groupings that could have been derived. Nonetheless, we have identified 12 broad clusters that represent a more sensible taxonomy of global health inequalities than other established classifications.

Conclusions

Traditional ad hoc comparisons of countries considered as similar such as New Zealand and Australia, or Canada and the USA, or nations within South-East Asia or sub-Saharan Africa can be misleading as these have been shown here to be dissimilar when grouped together by health outcomes. Our analysis has instead shown that countries such as New Zealand are more similar to Singapore, Canada and France, whereas Australia is more similar to Switzerland, Sweden and Japan based on all-cause mortality outcomes. The USA, on the other hand, is more similar to the UK and Germany. There are considerable disparities in life expectancy and health system performance across the 12 clusters of countries identified. There are no surprises in the dominance of OECD countries with highly developed healthcare systems being in the highest life expectancy clusters and African nations ravaged by HIV/AIDS epidemics (and the consequences of failed states) being included in the lowest life expectancy clusters. This geo-demographic classification system facilitates the comparison of global health inequalities and creates a more sensible rationale for international comparisons based on health outcomes.

What this study adds

- The comparison of global health inequalities between countries using cluster analysis based on health outcomes creates a more appropriate rationale for international comparisons and monitoring.
- The life expectancies and health system indicators of the countries allocated to each world cluster show the extent to which there is wider validity in this clustering.

Policy implications

- Global institutional policies and interventions to reduce health inequalities will benefit through more meaningful summaries of inequality based on health outcomes.
- Greater knowledge of the problem of global health inequalities can facilitate action such as that of the WHO Commission on Social Determinants of Health to promote debate and the uptake of policies that will reduce inequalities in health within and between countries.
- The methodology has potential for the monitoring of global health inequalities over time through the changing relative membership of countries within clusters.

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Competing interests
None

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